Possible Ways of Visualizing Uncertainty

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Goals

- Show some uncertainty visualization and apply them to illustrative problem
- Highlight visualization challenges and issues for working group discussion

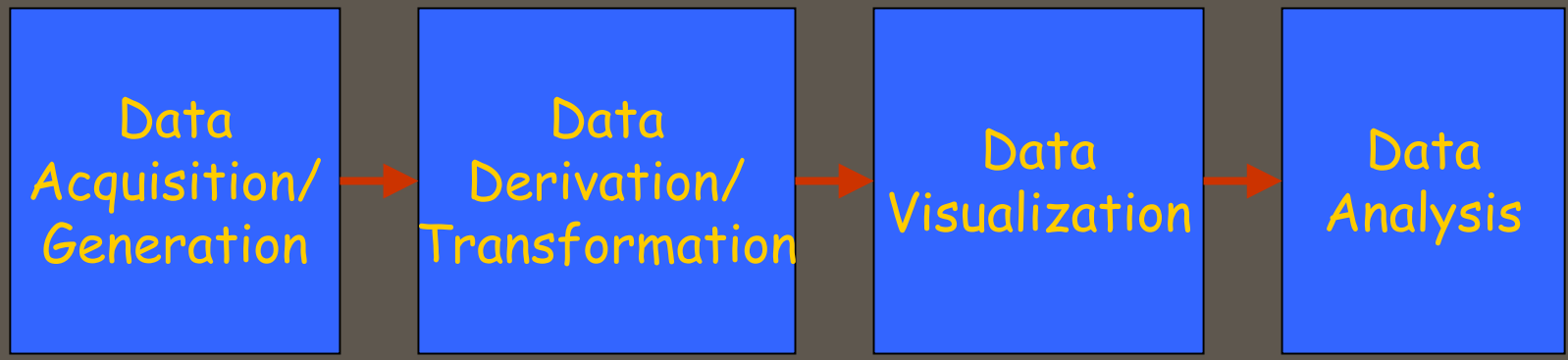
Caveats

- Approximately. 2 months to learn about problem and create some representative visualization
- unequal amount of time spent on each data set / bubble
- propagated uncertainty, not delta's
- different target users, needs, etc.

Why Uncertainty Visualization

- big data (cannot visualize everything)
- little data (filling in the holes)
- noisy, spotty data
- conflicting data / measurements
  - multiple algorithms
  - multiple models, geometries, …

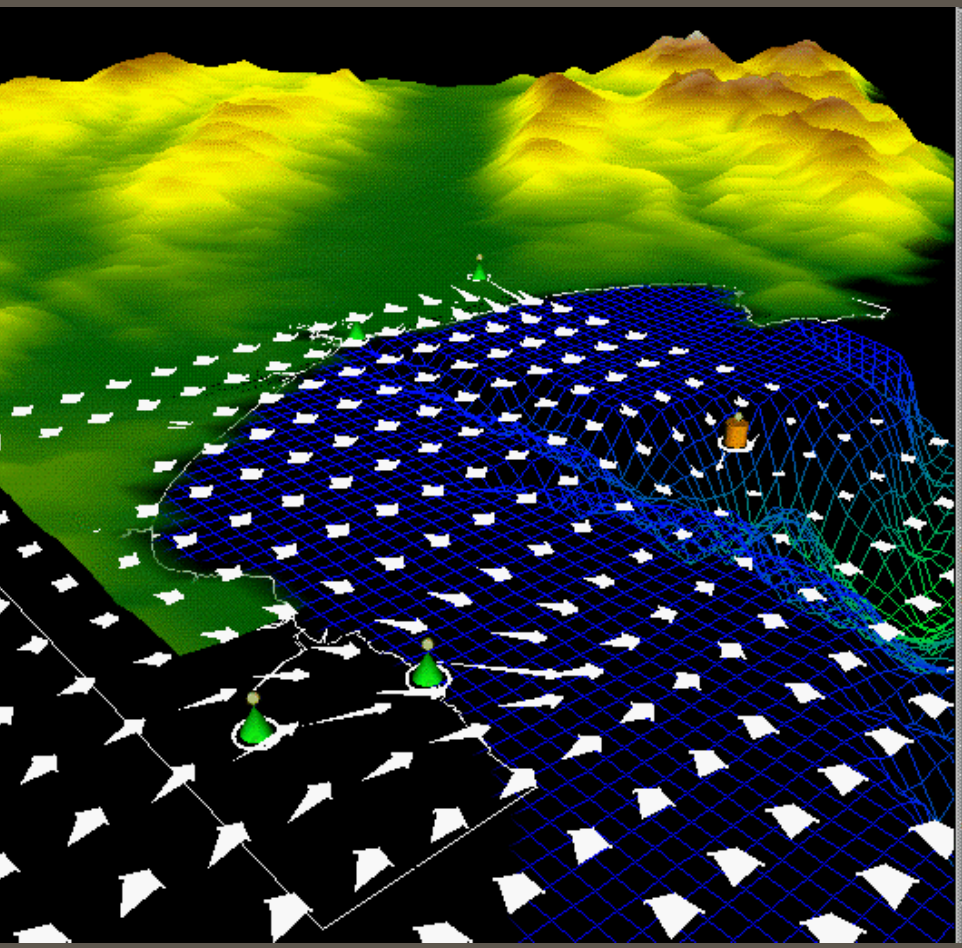
Sources of Uncertainty



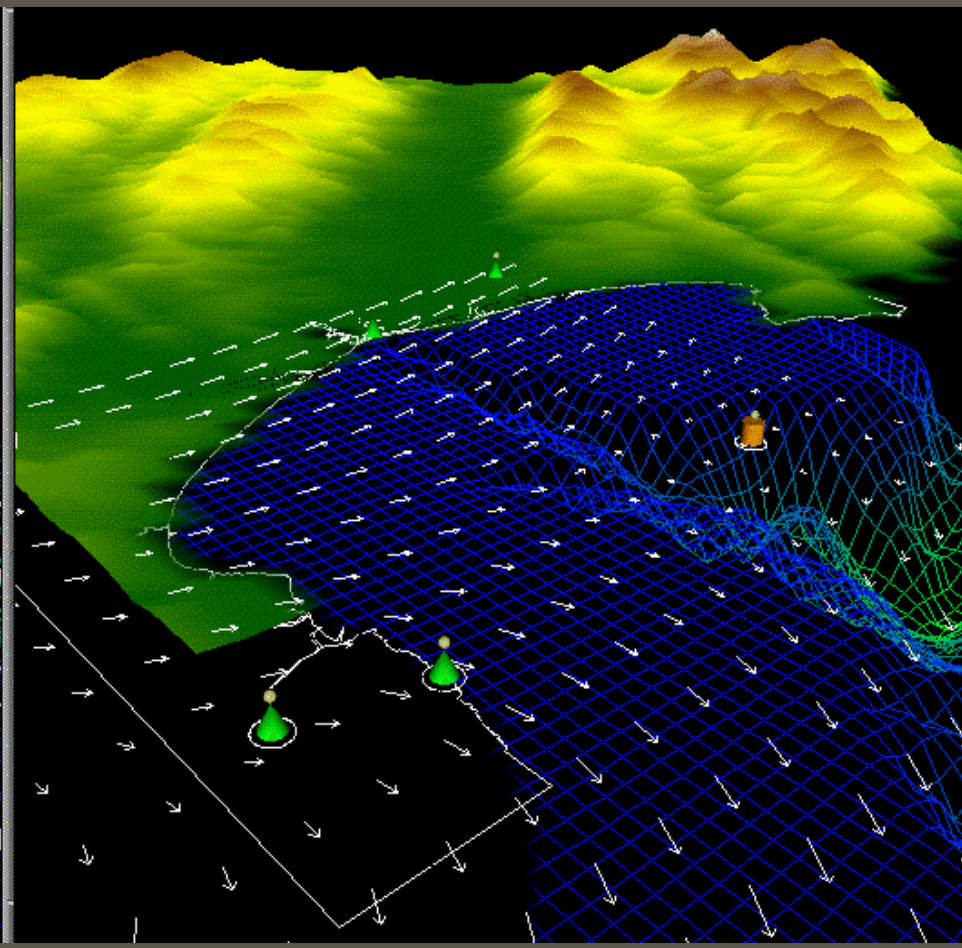
- Simplifications in modeling, unknowns in environments, …
- Calibration drifts, range, resolution, …
- Numerical accuracy, parameter sensitivity, …
- resampling, interpolation, visualization, …

Some Uncertainty Vis'n

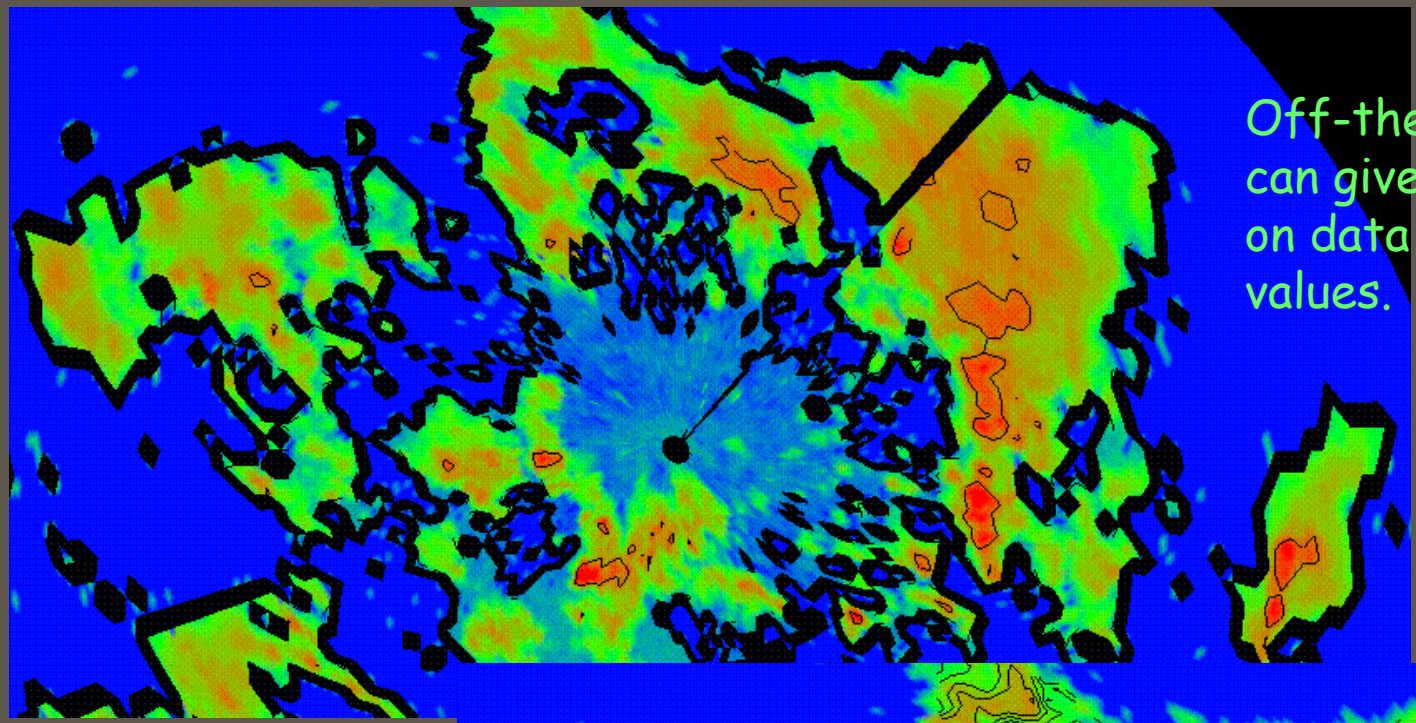
- 0 dimension -- glyphs
- 2 dimensions -- contours
- 3 dimensions -- isosurfaces,
  volume rendering



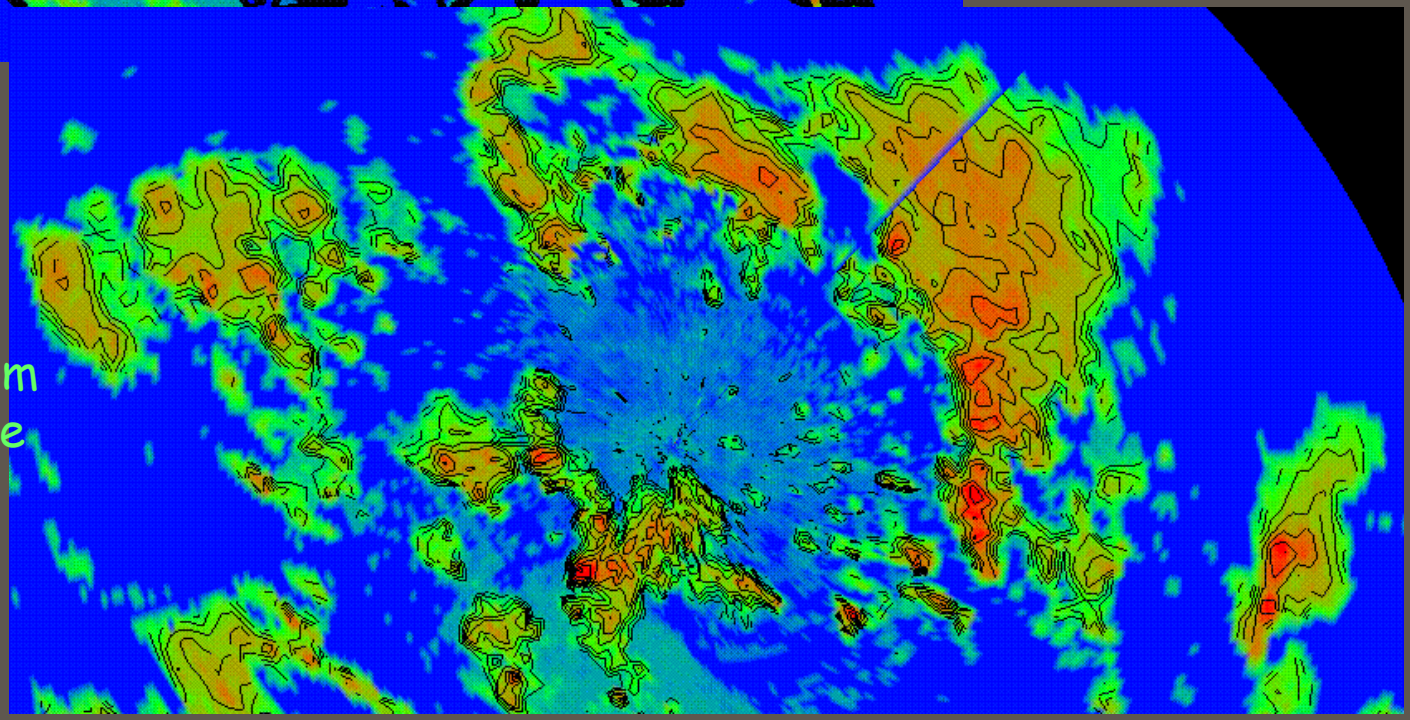
Uncertainty glyphs can encode uncertainty in vector direction and magnitude



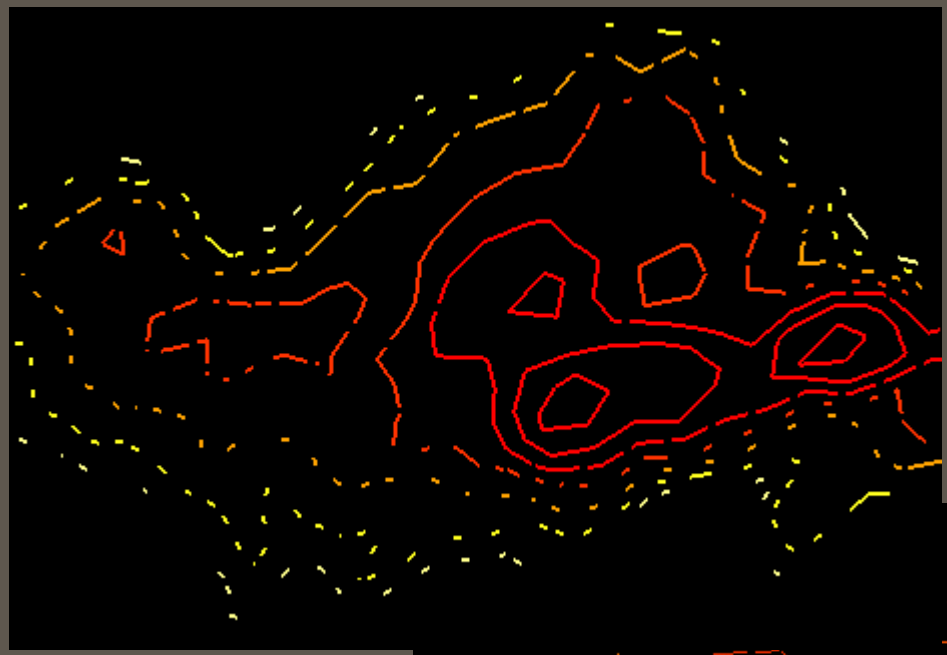
Regular arrow glyphs give false sense accurate vector heading and magnitude.



Off-the-shelf software can give incorrect contours on data with lots of missing values.

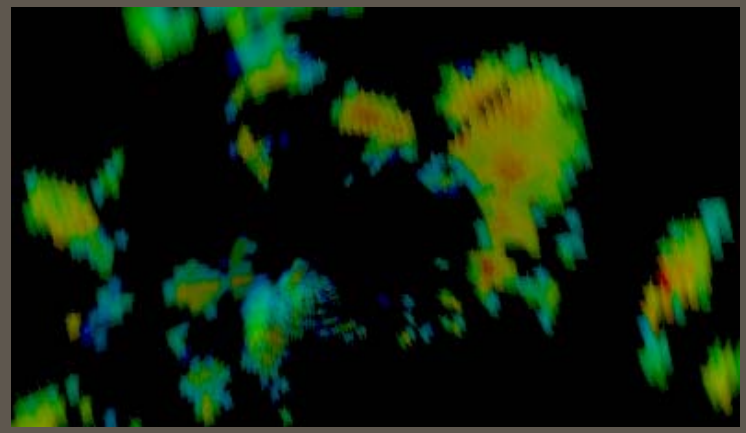


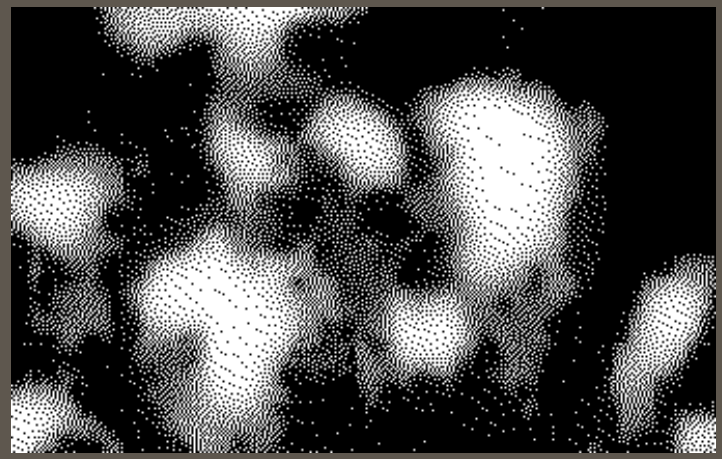
Modifications to contouring algorithm to account for large number of missing values.

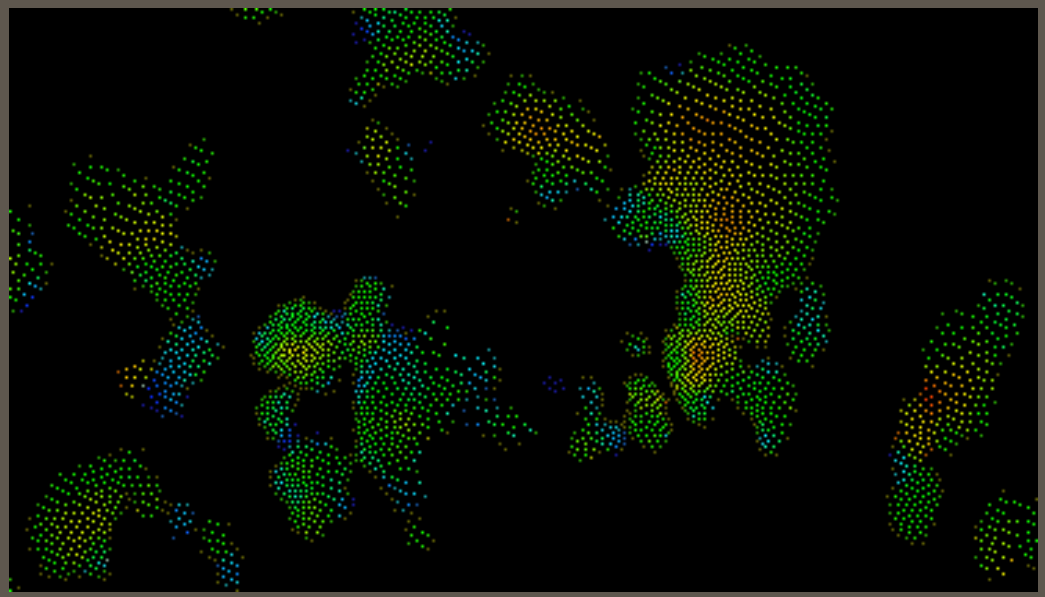


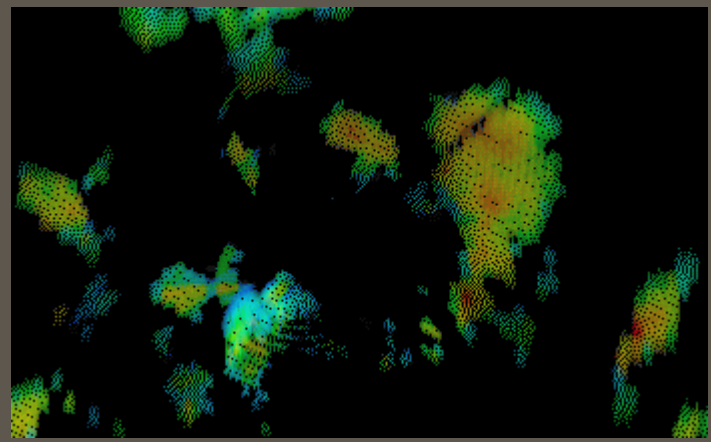
Modification to contour algorithm to give indication of uncertainty using dashed lines. Solid lines indicate regions higher certainty in the underlying data.

Volume rendering indicating uncertainty information in the data. Here, the data field and the uncertainty information fields are volume rendered independently. A post-process speckle is applied to the latter and used to composite with the former to produce the resulting images on the bottom.







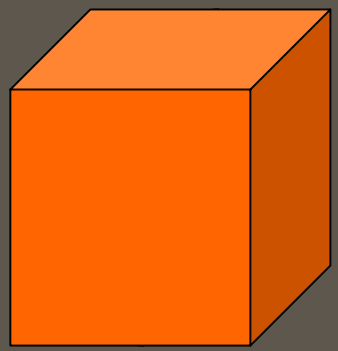


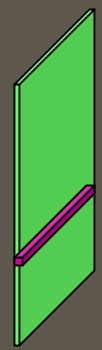
Illustrative Problem Overview

Ocean

Acoustic/Signal Processing

Target estimate





Environmental uncertainty

Propagation loss

Bearing, detection likelihood

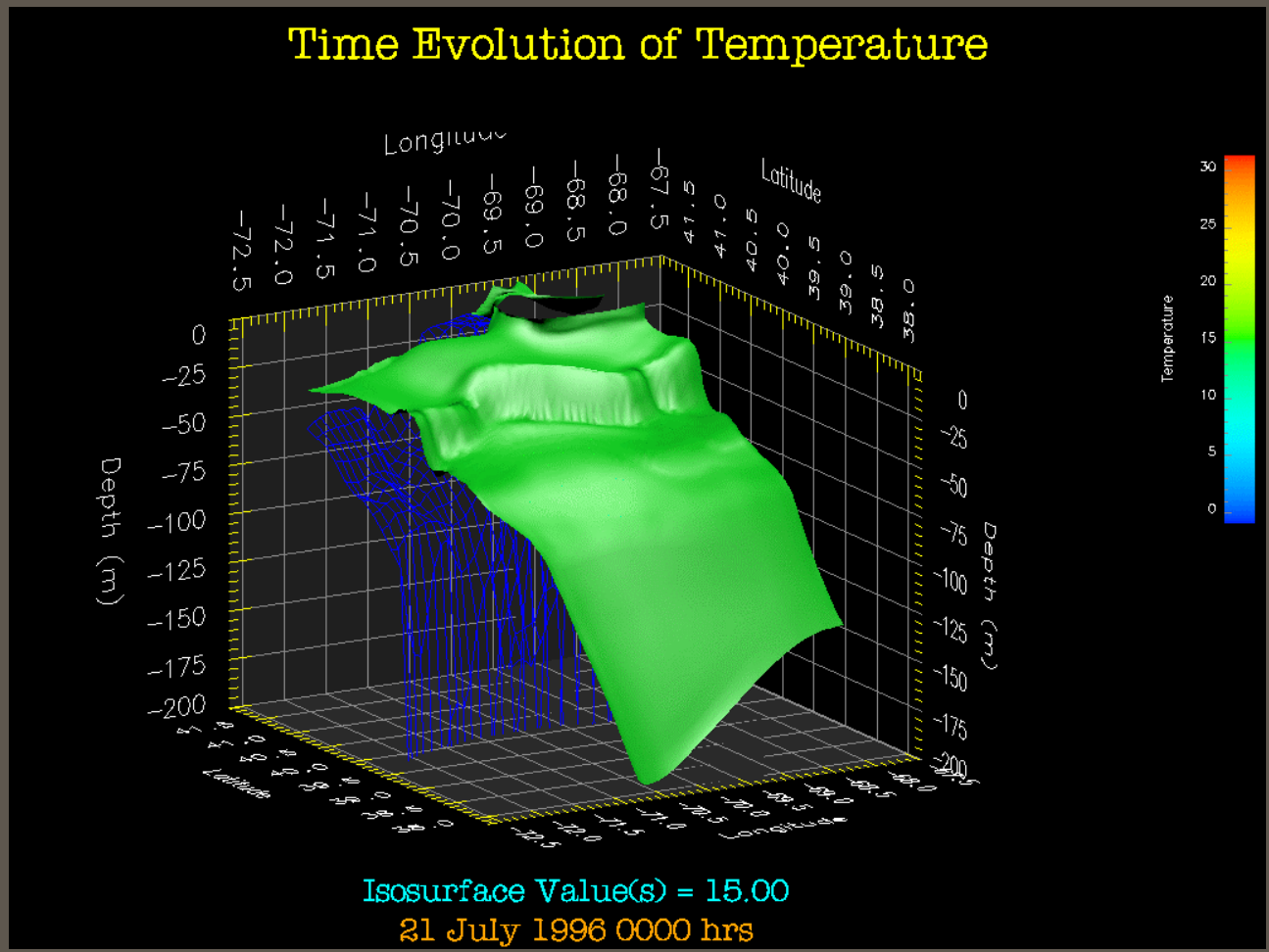
"days"

"minutes"

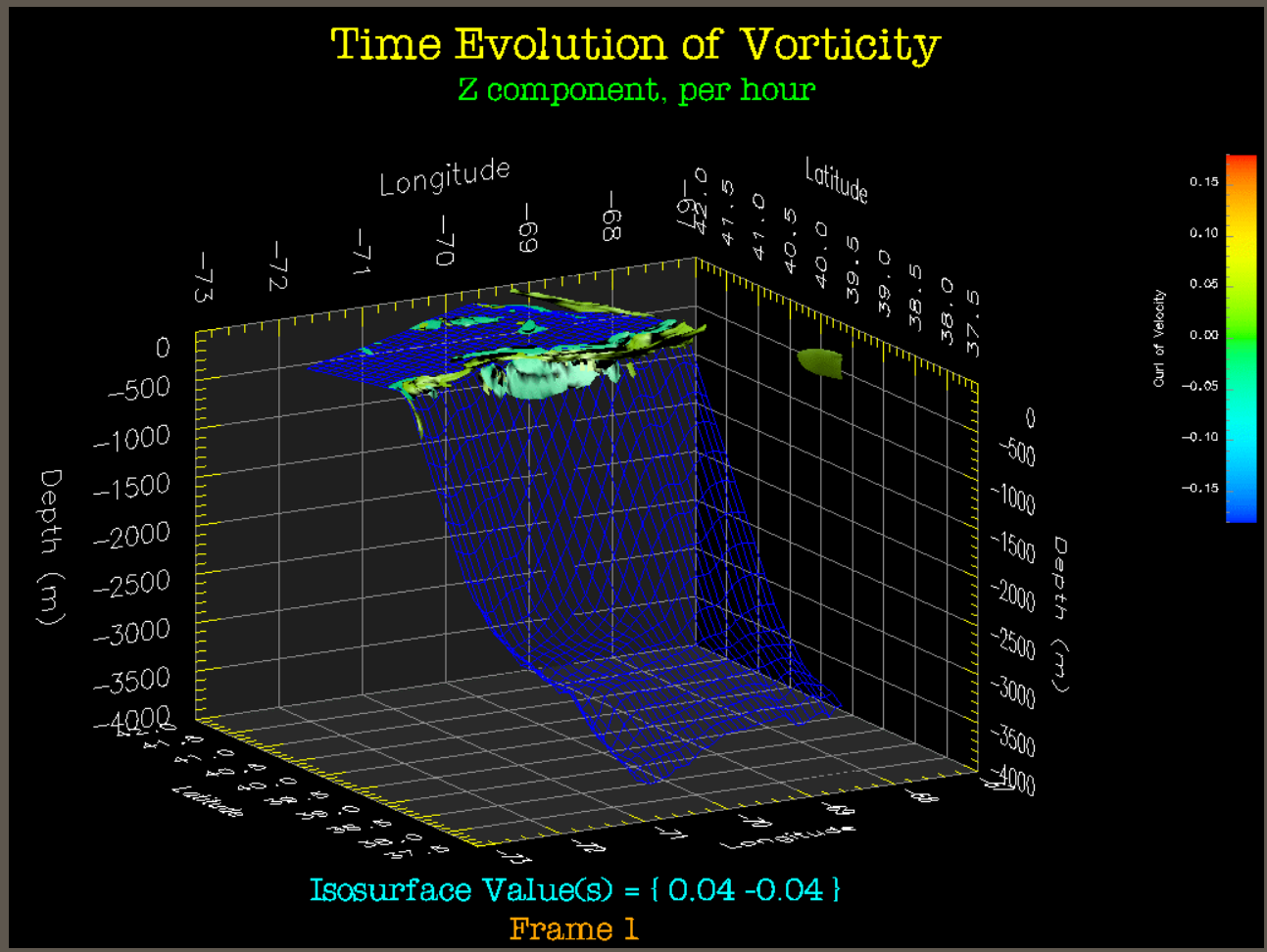
Ocean Model

- 3D + time:
  - 4 frames / day
  - 72 x 65 x 42 depths x 81 frames
- Salinity, temperature, velocity
- Sound speed transects with statistics
- Mean & standard deviation derived from time frames

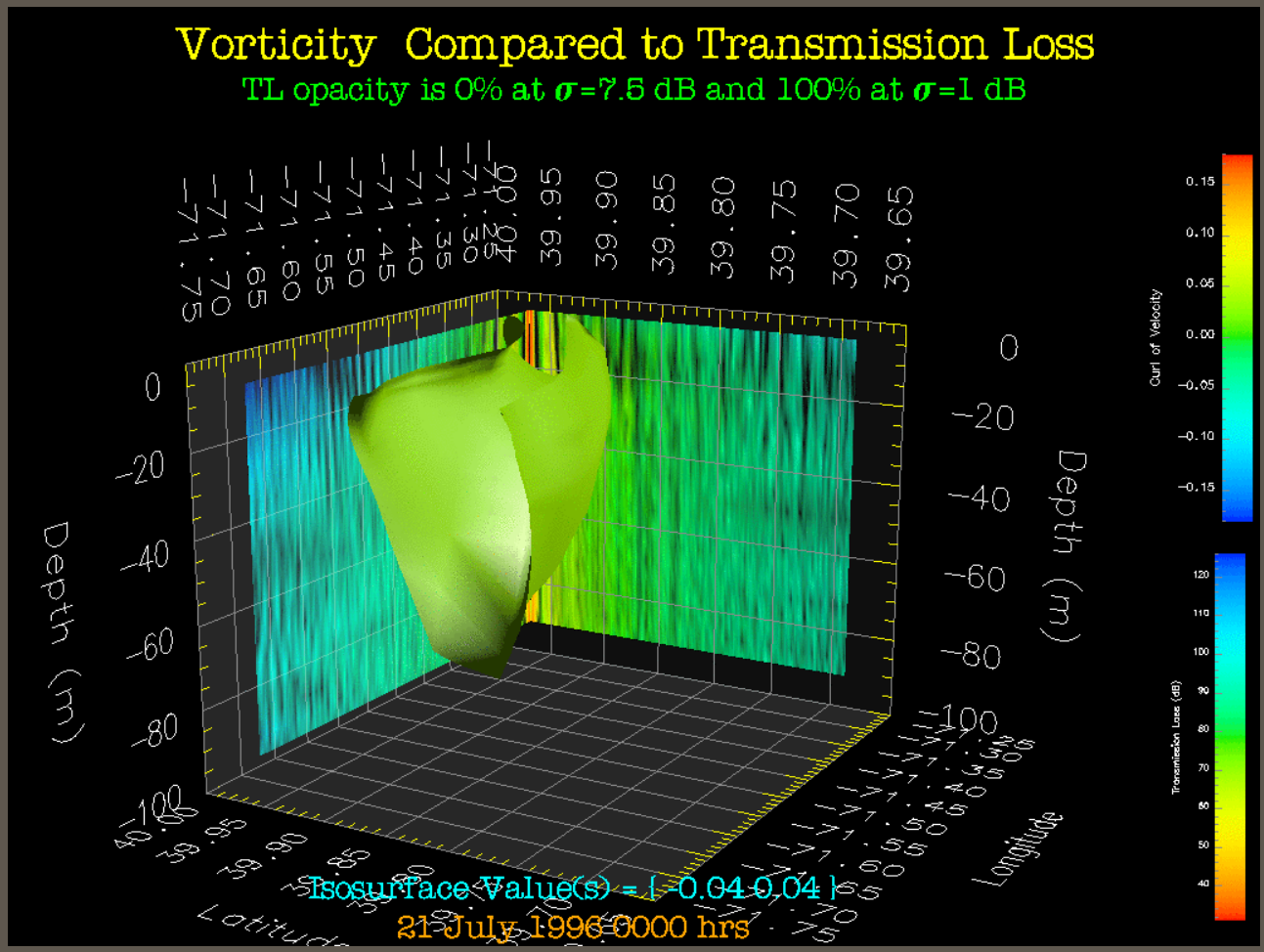
Temperature: 15C



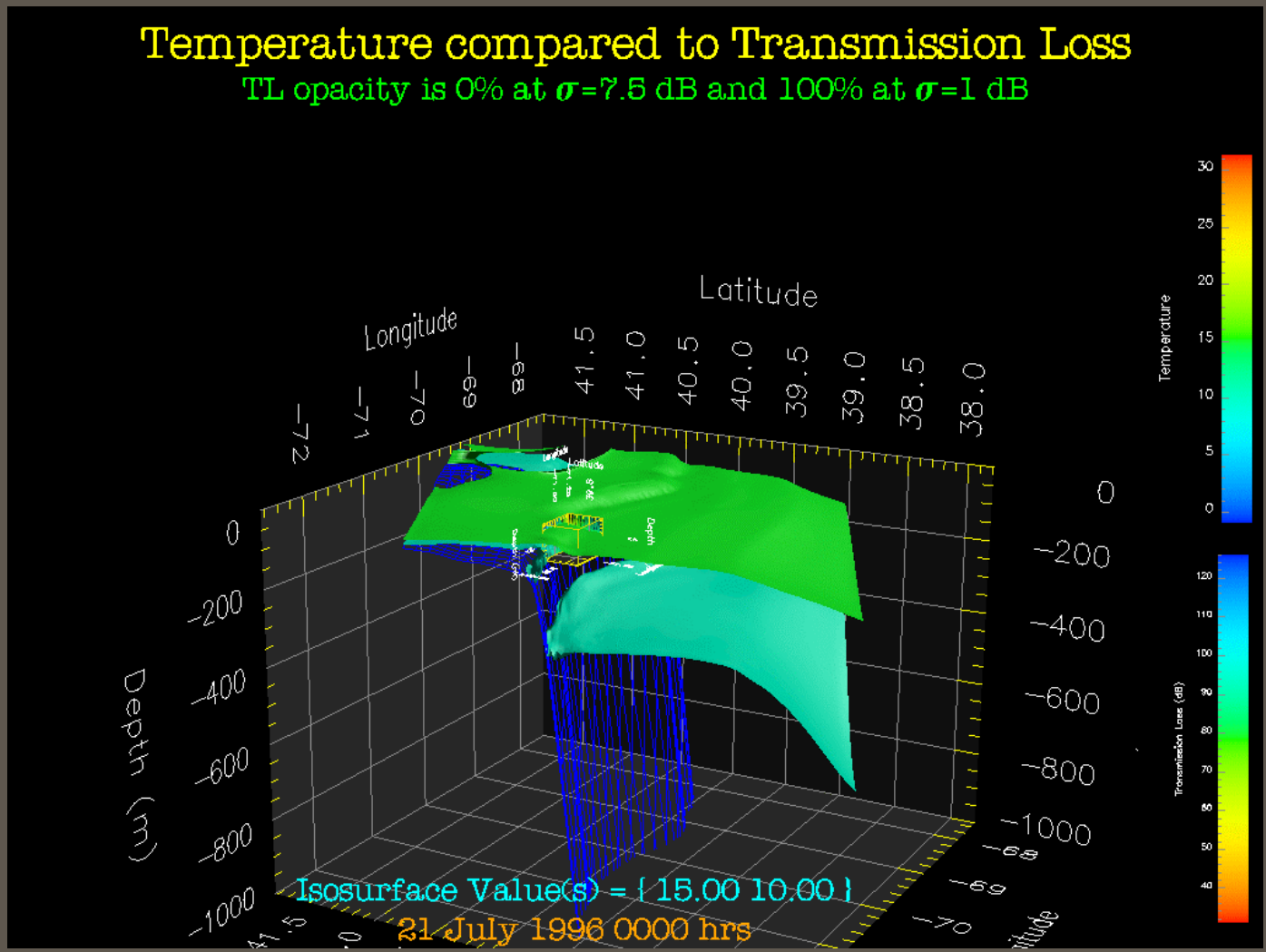
Vorticity field



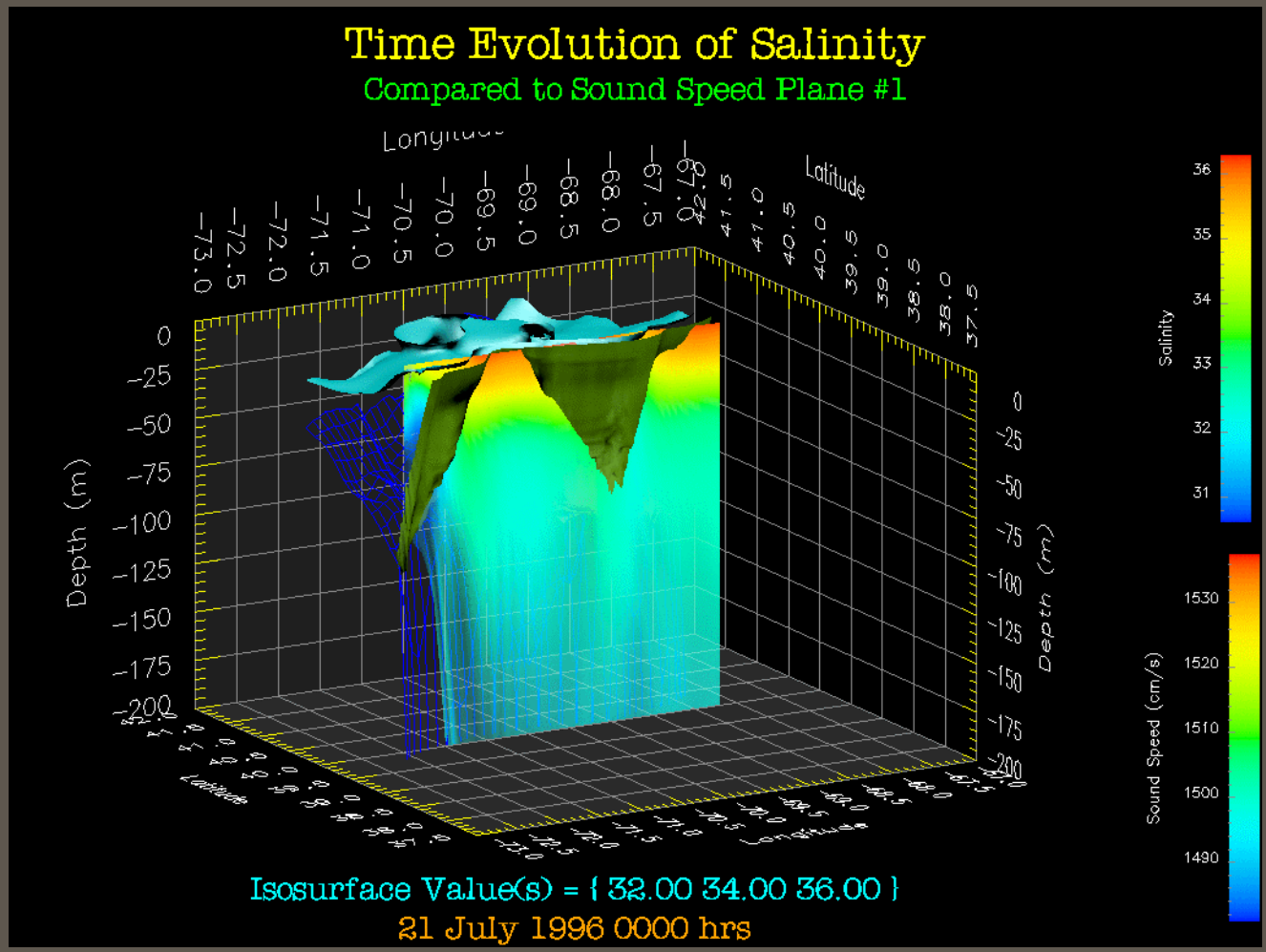
Vorticity + TL



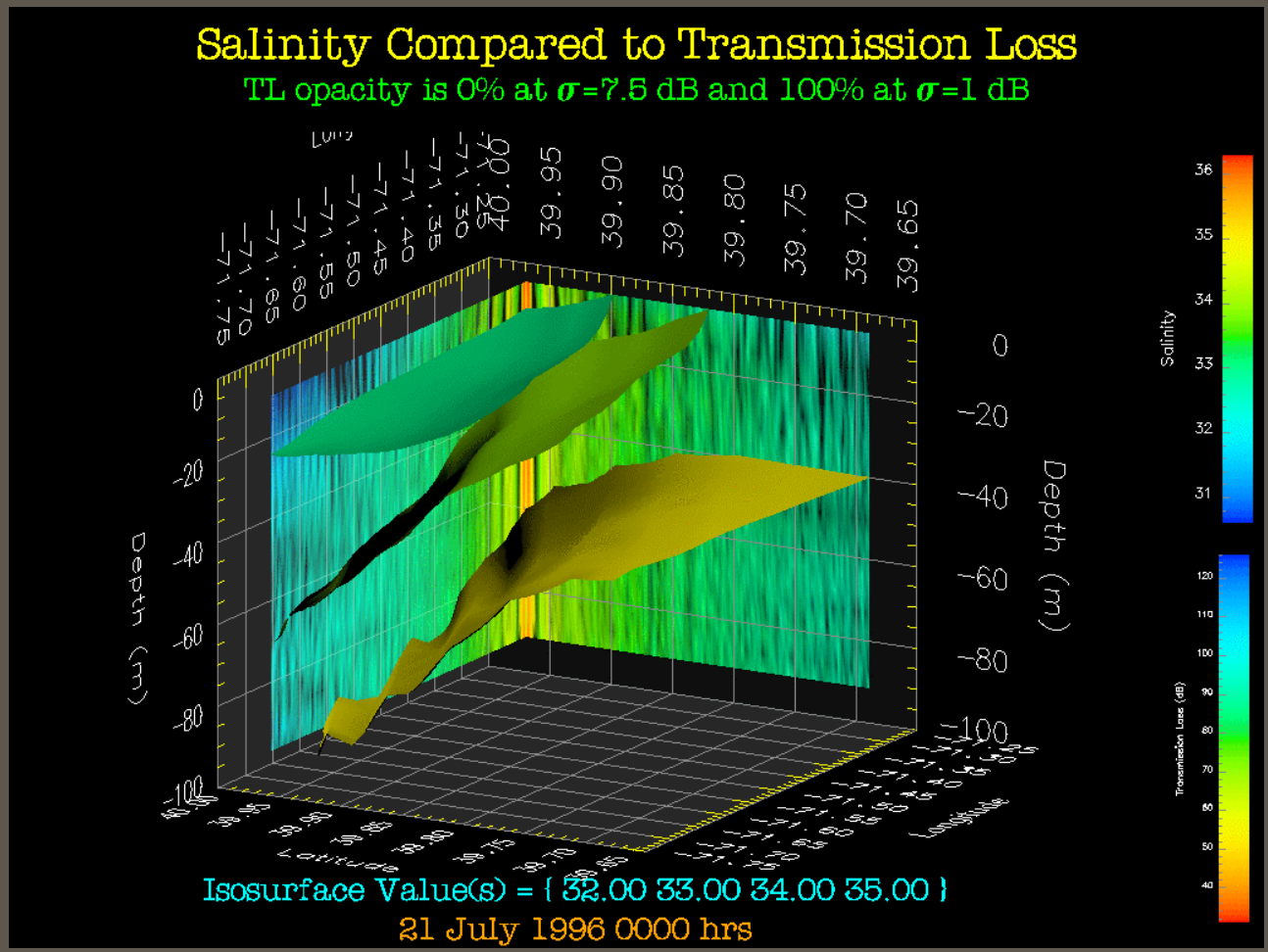
10C & 15C Temps & TL



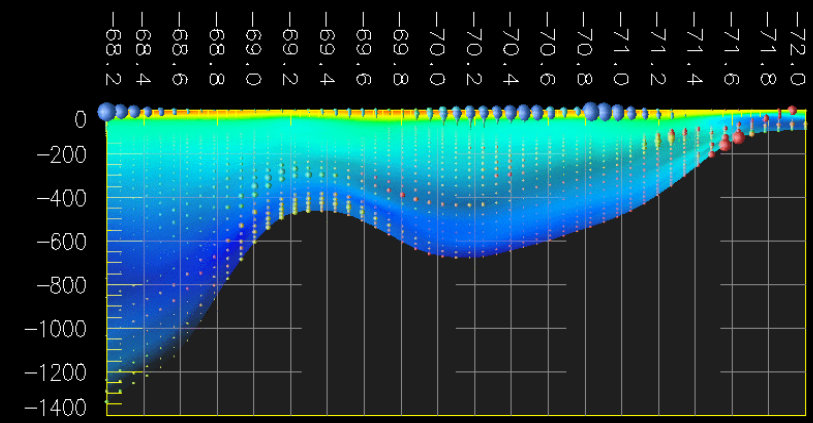
Salinity + Soundspeed #1



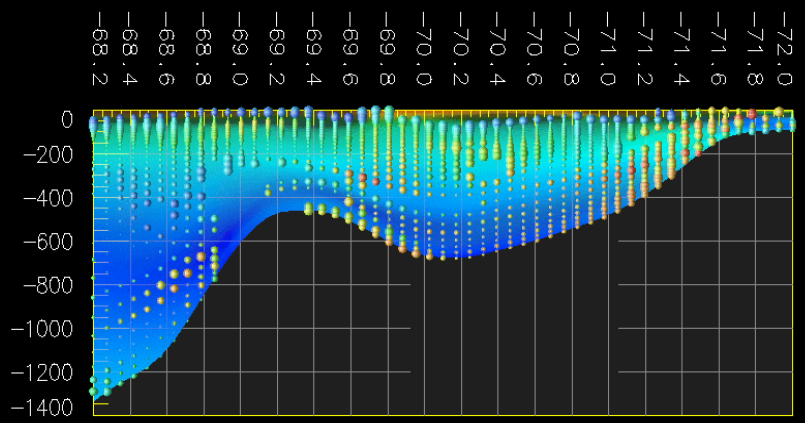
Salinity + TL


Salinity Compared to Transmission Loss
TL opacity is 0% at σ=7.5 dB and 100% at σ=1 dB
Depth (m)
Latitude
Longitude
Salinity
Transmission Loss (dB)
Isosurface Value(s) = { 32.00 33.00 34.00 35.00 }
21 July 1996 0000 hrs

Soundspeed: var, kurt, skew

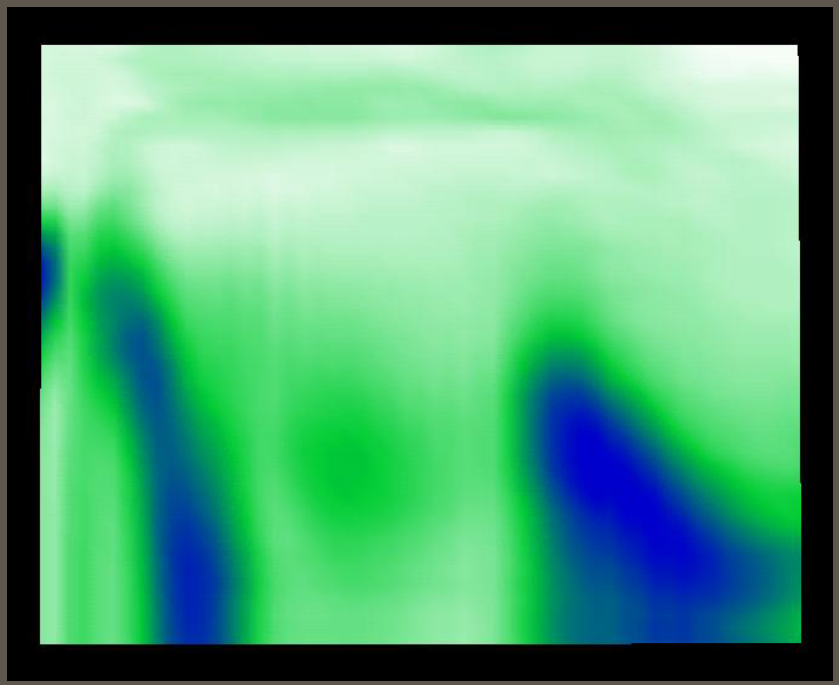


Color = soundspeed
transparency = low variance
glyph color = skewness (green = 0)
glyph size = kurtosis

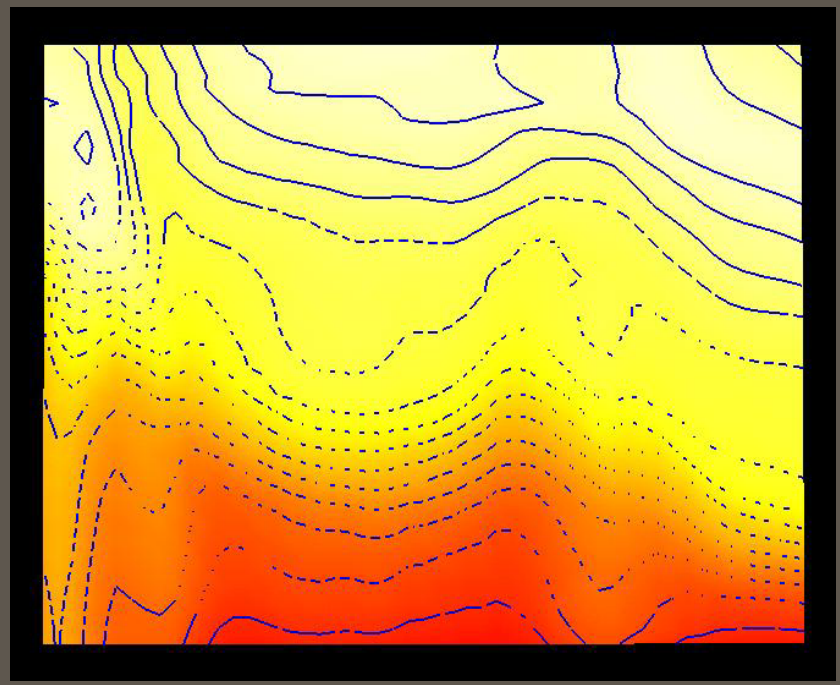


Color = soundspeed
transparency = high variance
glyph color = skewness (-1..1)
glyph size = kurtosis (2..4)

Soundspeed (42 levels,80 realizations)

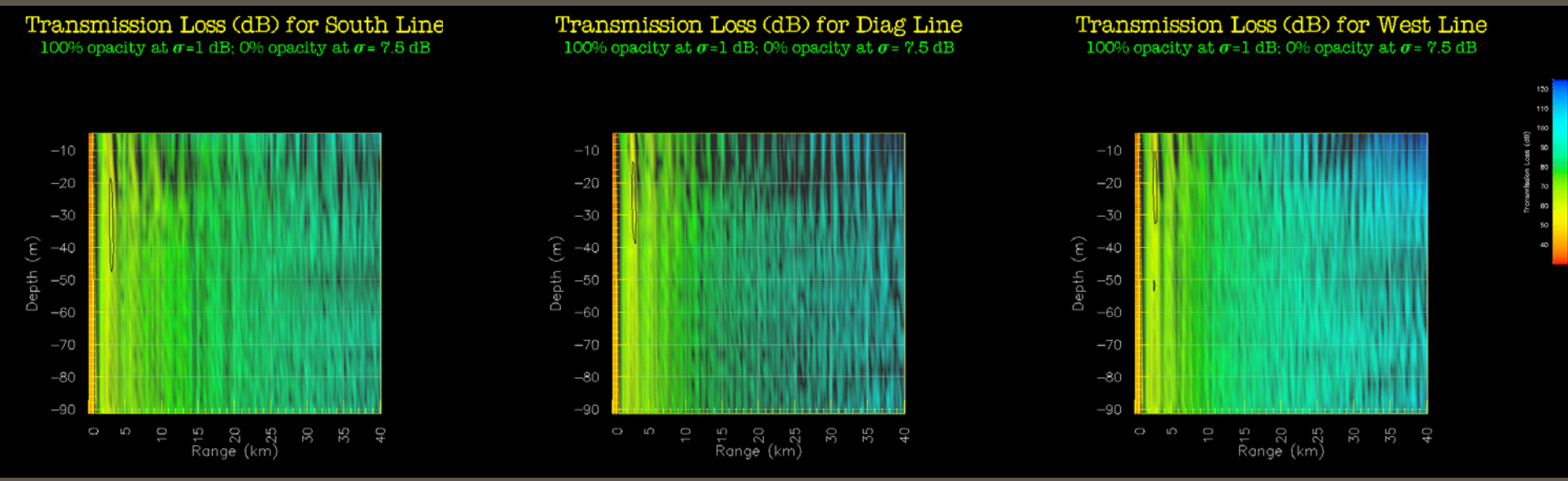


Standard deviation colored

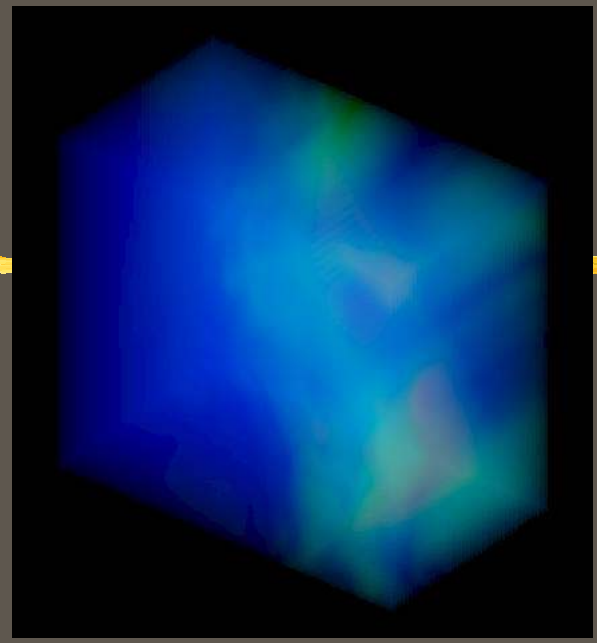


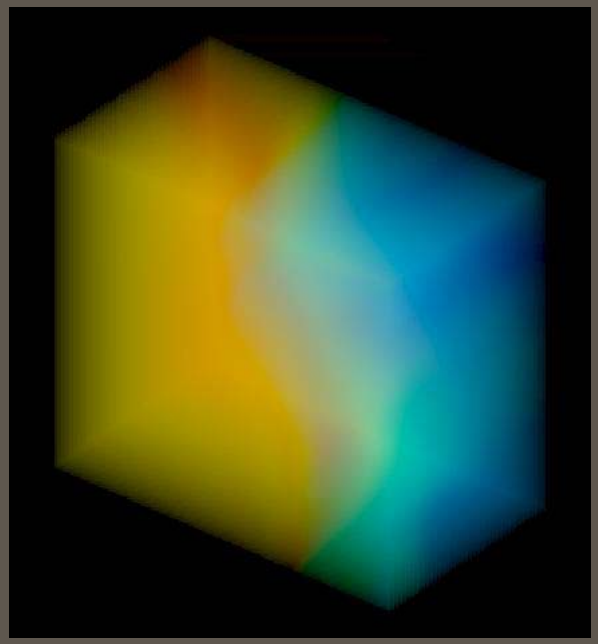
Soundspeed colored/contoured, dashes based on sdev

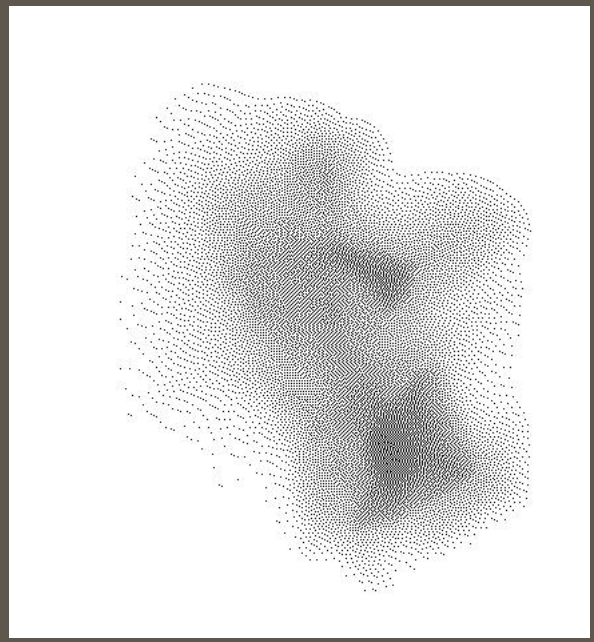
Transmission Loss

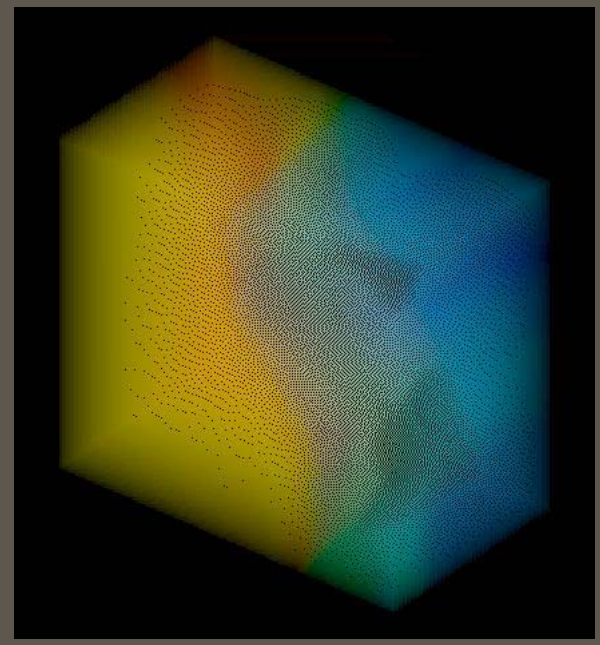


Color = transmission loss
transparency = variance





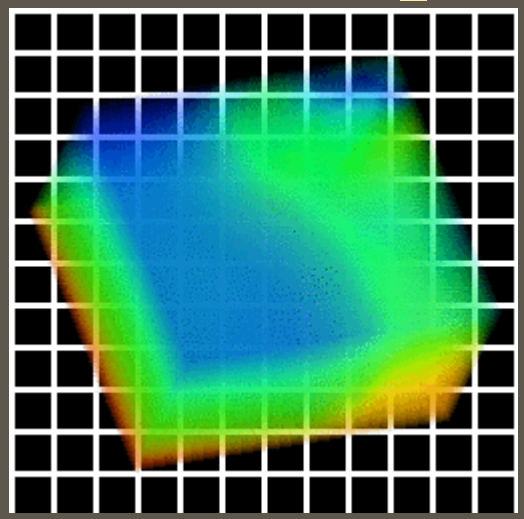


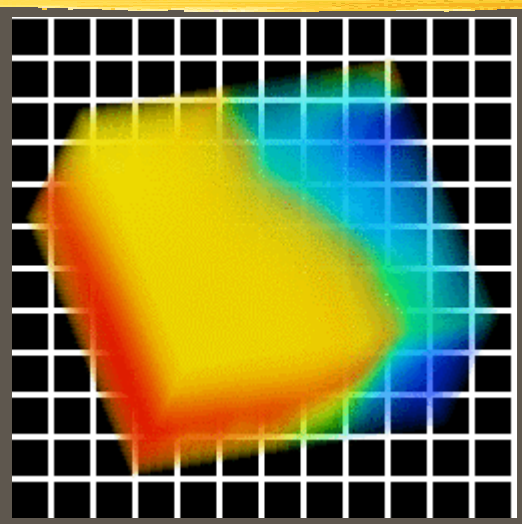


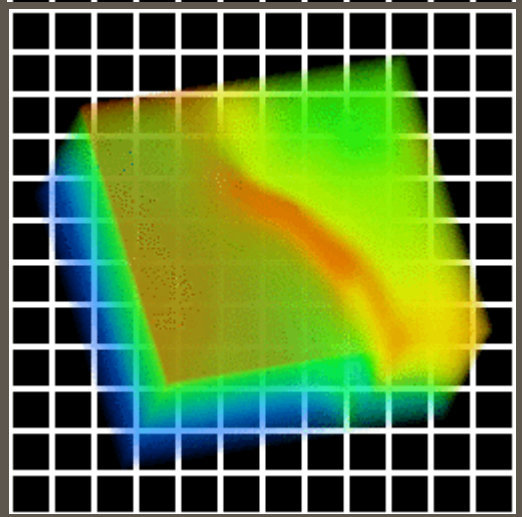
Mean salinity

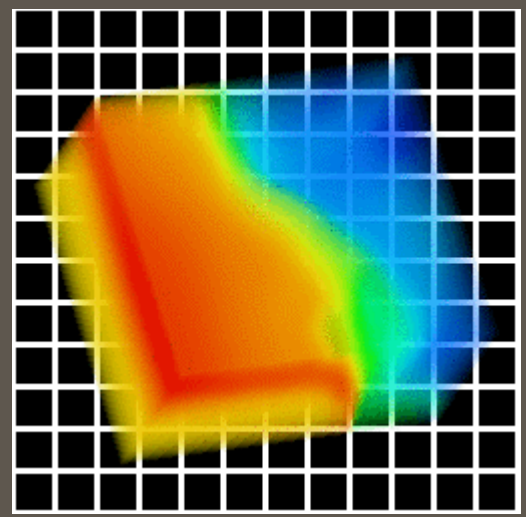
Sdev salinity

Increasing Opacity Mapping



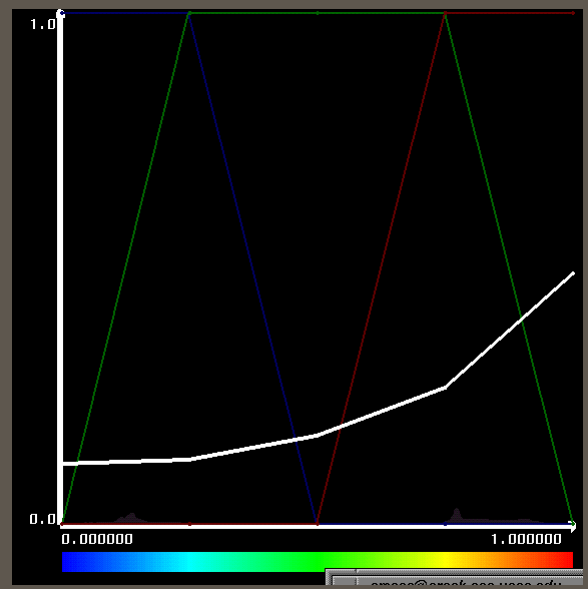




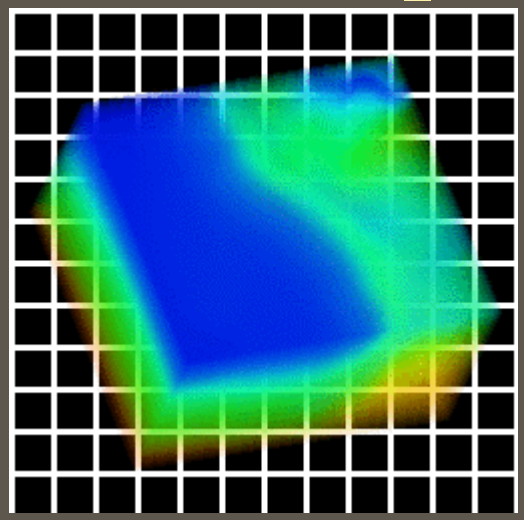


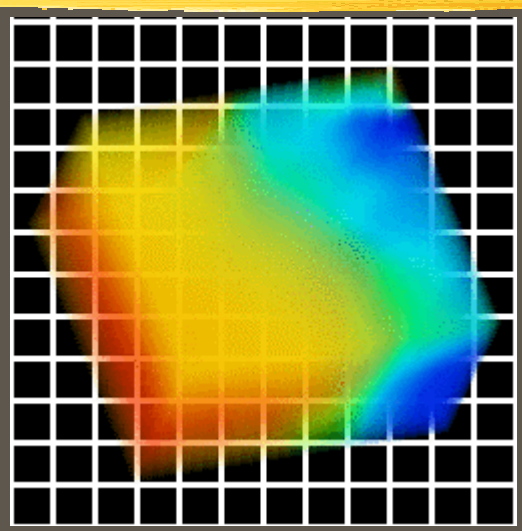
temperature

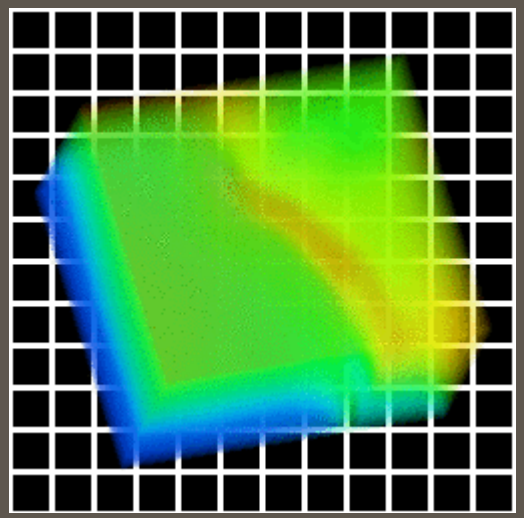
salinity



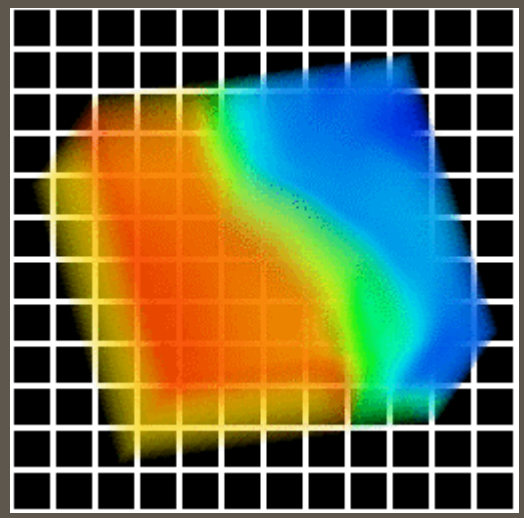
Decreasing Opacity Mapping



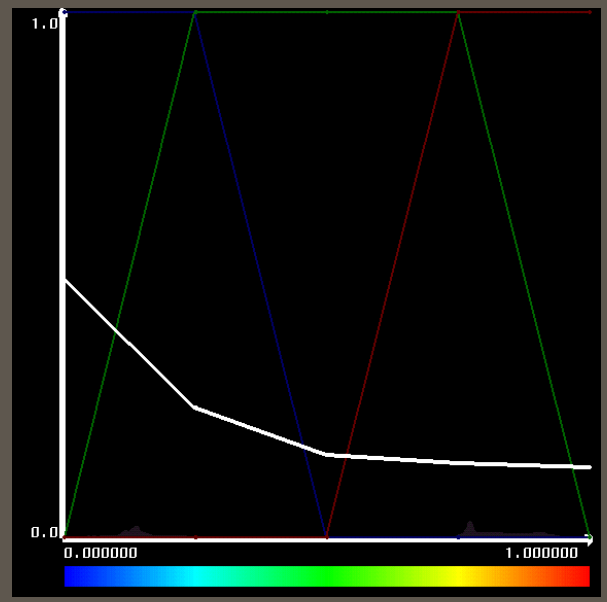




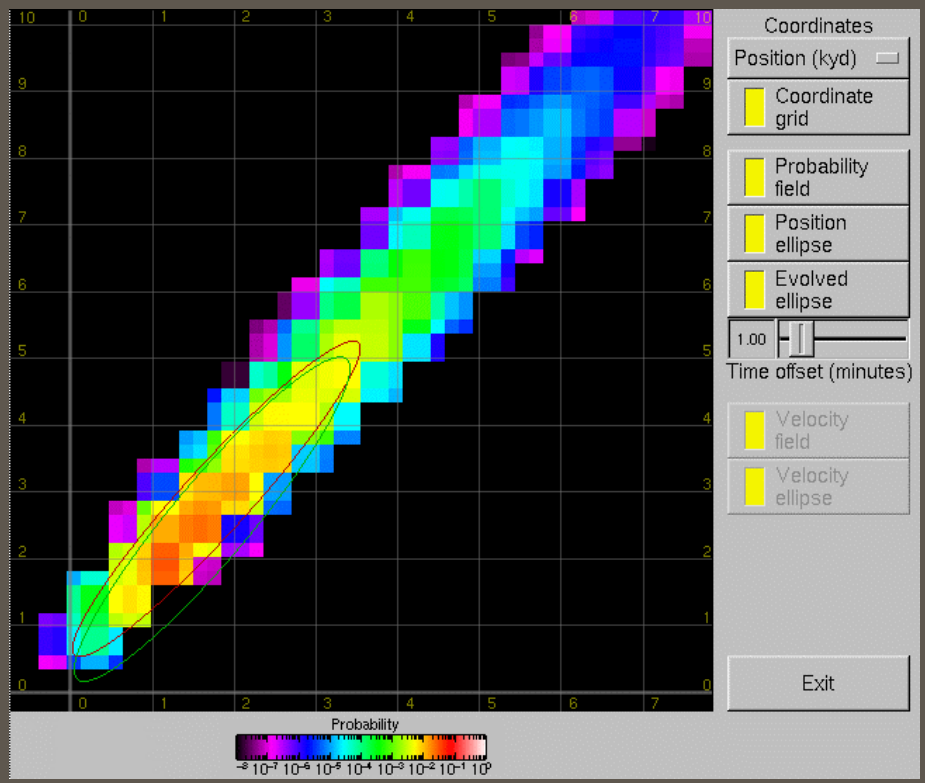
temperature



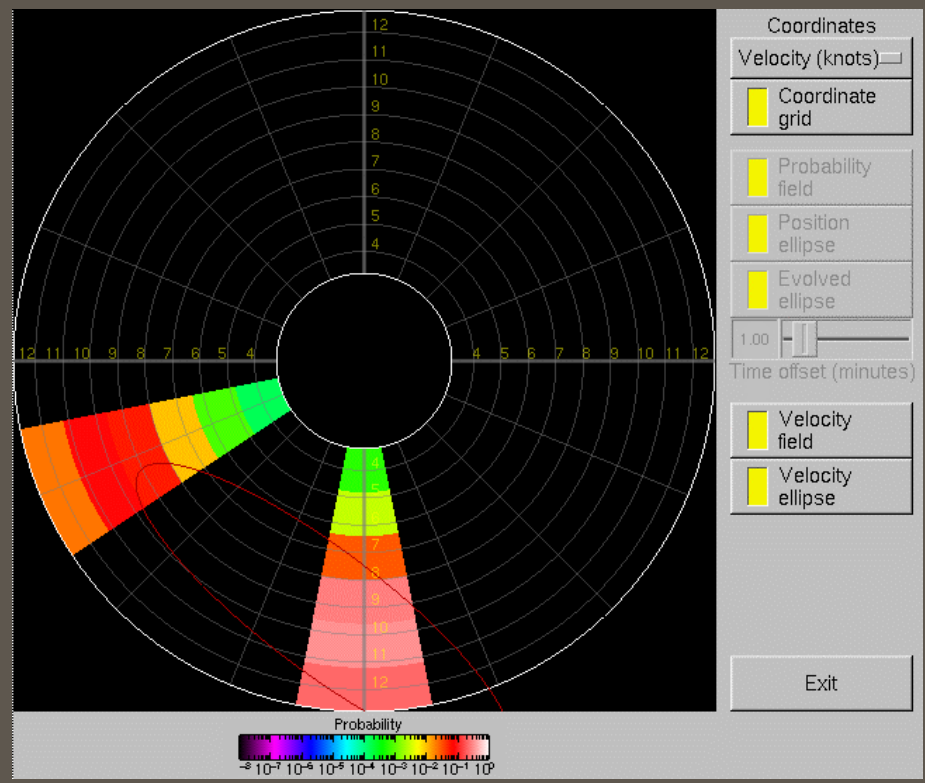
salinity



Target State Estimate



Position



Velocity

Red ellipse = 2 σ now

Grey ellipse = 3 σ in 1 minute

Visualization Challenges

- Uncertainty visualization
  - multi-dimensional visualization, visual mapping
  - range, standard deviation, pdfs, matrices, ..
    - Population size, pdf shape, etc.
  - Sonification & haptics
- Feature extraction & tracking
  - range displacements (location of caustic), fronts, convergence zones, acoustic inversion layers, temperature pockets/ducts/mixing, …
- Comparative visualization
  - go beyond side-by-side
  - show propagation of uncertainty through process

Users

- Who are the users?
- What are they looking for in the data?
- What's important in the data?
- How is data currently being visualized?

Other Issues

- Data format (e.g. HDF, netCDF)
- Tools (e.g. matlab, opendx, avs)
- Uncertainty representation (scalar, distribution, etc.)
- Portability, web access
- Speed, cost

Summary

- Presented some uncertainty visualization techniques on different aspects of the illustrative problem
- Does not show effects of uncertainty transfer/propagation in end-to-end fashion
- Challenges in each and across the different bubbles in DRI schematic

Whew!